LOCATION BASED HANDOFF FOR MOBILE DEVICES

DESCRIPTION

The present invention relates to the communications arts. It finds particular application in the wireless local area network systems (WLAN) and will be described with particular reference thereto. However, the invention may also find application in other communications systems.

WLAN is a flexible data communications system implemented as an extension to, or as an alternative for, a wired local area network (LAN). Typically, WLAN uses radio frequency (RF) technology to transmit and receive data over the air without relying on any physical connection. The data being transmitted is superimposed on the radio carrier so that it can be accurately extracted at the receiving end. Multiple radio carriers exist in the same space at the same time without interfering with each other, provided that the radio waves are transmitted on different radio frequencies. To extract data, a radio receiver tunes in one frequency while rejecting all other frequencies.

In a typical WLAN system, a transmitter/receiver device, called an access point, connects to the wired network from a fixed location using standard cabling. Typically, the access point receives, buffers, and transmits data between the WLAN and the wired network infrastructure. Generally, a single access point supports a small group of users and can function in a range of approximately thirty to fifty meter radius. End users access the WLAN through WLAN adapters, which are implemented as PC cards in notebook or palmtop computer, as cards in desktop computers, or integrated within hand-held computers. WLAN adapters provide an interface between the client network operating system (NOS) and the airways via antenna.

Generally, in a large facility such as an office, a hospital, a manufacturing facility, or the like, it is necessary to install more than one access point. The access points are installed to blanket the area with overlapping coverage cells so that the clients can roam seamlessly throughout the area without ever loosing contact. When a client moves from one area to another, a handoff has to be performed to assign new system resources associated with the new access point. The handoff involves executing a set of negotiations between the mobile device and a central computer. As a result, the client is handed over from one access

point to another in a way that is invisible to the client. Generally, a handoff improves performance of the system at the expense of tying up more system resource.

Efficient and timely handoff procedures are very important within the WLAN which has small operating cells and great demand for increased communications system capacity. A typical approach for a mobile device handoff is to scan all radio frequencies within the WLAN operational space to determine a relative strength of the mobile device signal. However, with many users being hooked up to the WLAN and numerous crossings of cells boundaries, this approach considerably ties up system resources and slows down communications throughput.

There is a need for technique that provides adaptive, fast, efficient, seamless, and cost effective handoff of mobile units in WLAN. The present invention contemplates a new and improved method and apparatus that overcomes the above-reverenced problems and others.

In accordance with one aspect of the present invention, a communications system is disclosed. A plurality of mobile wireless units and a plurality of access points, each surrounded by an associated operational cell, are located within a defined area of a WLAN. The operational cells are overlappingly disposed in the defined space. Each access point operates at a dedicated frequency. A means tracks a movement of at least one mobile device within the defined space. A means scans identified scanning frequencies of nearby access points to measure actual signal strengths between the at least one mobile device and each of the nearby access points. A means calculates at least a position of the at least one mobile device by comparing the actual signal strengths with a map of relative signal strengths at predefined locations in the defined space. A means assigns an access point with a strongest signal to the at least one mobile device based on its location and the map of relative strengths in the defined space.

In accordance with another aspect of the present invention, a method for handing off at least one mobile device from one access point to another in a wireless local area network is disclosed. A movement of the at least one mobile device within the defined space is tracked. Identified scanning frequencies corresponding to each of an identified plurality of nearby access points are scanned. Actual signal strengths at each of the identified frequencies between the at least one mobile device and the identified access points are measured. At least a position of the at

least one mobile device is calculated by comparing the actual signal strengths with a map of relative signal strengths at predefined locations in the defined space. An access point with a strongest signal is assigned to the at least one mobile device based on the calculated position and the map.

One advantage of the present invention resides in the fast and efficient handoff of the wireless mobile units in the wireless local area network.

Another advantage resides in the cost effective handoff.

Still further advantages and benefits of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiments.

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 schematically shows a portion of a WLAN communications system; and

FIGURE 2 schematically shows a part of a WLAN communications system in accordance with the present application.

With reference to FIGURE 1, a wireless local area network **10** includes one or more mobile devices or units $\mathbf{12_1}$, $\mathbf{12_2}$, ..., $\mathbf{12_n}$. Preferably, the mobile devices $\mathbf{12_1}$, $\mathbf{12_2}$, ..., $\mathbf{12_n}$ are palm computers, notebook computers, held-hand devices, PDAs, pagers, desktop computers, or any other devices which can be configured for wireless communications. Generally, the network **10** couples multiple access points or stations $\mathbf{14_1}$, $\mathbf{14_2}$, ..., $\mathbf{14_n}$ (only six access points are shown for simplicity of illustration), which are distributed throughout a defined area or space **16** to provide wireless service to the mobile devices $\mathbf{12_1}$, $\mathbf{12_2}$, ..., $\mathbf{12_n}$ which operate within the space **16** and are configured to communicate with the access points $\mathbf{14_1}$, $\mathbf{14_2}$, ..., $\mathbf{14_n}$. Each access point $\mathbf{14_1}$, $\mathbf{14_2}$, ..., $\mathbf{14_n}$ has a finite operational range or access point cell $\mathbf{18_1}$, $\mathbf{18_2}$, ..., $\mathbf{18_n}$, which is typically 30-50

meters. Each access point **14_1, 14_2, ..., 14_n** operates within its own dedicated radio channel with a known radiofrequency. Because the operational ranges **18_1, 18_2, ..., 18_n** overlap within the area **16**, each channel operates at a unique radiofrequency to prevent concurrent communications of the mobile device **12_1, 12_2, ..., 12_n** with more than one access point at the same frequency. Of course, it is also contemplated that other WLAN designs can be used, in which the frequencies can be reused.

The access points **14_1, 14_2, ..., 14_n** are wired or otherwise connected into a wired network infrastructure or a local area network **20**. A central computer **22**, which is connected to the local area network **20** and includes associated software means **24** and hardware means or processor **26**, oversees the operations of the WLAN system **10** and, preferably, provides an interface to various systems and/or applications which are available within the local area network **20**.

Each access point **14_1, 14_2, ..., 14_n** includes an antenna or receiving/transmitting means **30** to communicate bi-directionally with the mobile devices **12_1, 12_2, ..., 12_n**. E.g., the access points **14_1, 14_2, ..., 14_n** at least receive, buffer, and transmit data between the mobile devices **12_1, 12_2, ..., 12_n** and the wired network **20**. Each mobile device **12_1, 12_2, ..., 12_n** includes associated hardware means **32** and software means **34**. The hardware and software means **32, 34** are implemented or integrated into the mobile devices **12_1, 12_2, ..., 12_n** to provide an interface between the mobile devices **12_1, 12_2, ..., 12_n** and the receiving/transmitting means **30**.

With continuing reference to FIGURE 1, when the mobile device **12_1** is in the cell **18_1**, it communicates with the access point **14_1**. As the mobile device **12_1** moves within the defined area **16**, the processor **26** executes a set of instructions and, if the handoff is determined to be necessary, handoffs the mobile unit **12_1** to another access point as will be discussed in a greater detail below.

With reference to FIGURE 2, an initial signal strengths determining means or computer routine or algorithm **38** determines initial signal strengths, i.e. signal gradients, at predefined locations. Optionally, the initial signal strengths determining means **38** defines the initial signal strengths at the predefined locations statistically. A mapping means **40** maps the initial signal strengths into the defined space **16**. A two- or three-dimensional geographical signal strength map of the area **16** indicating all of the stations or access points **14_1, 14_2, ..., 14_n**, associated operational frequencies, and the

defined initial signal strengths are stored in a database or an area map memory **42**. Preferably, the database **42** is located at the central computer **22**. Optionally, the database **42** is located within the WLAN **10**, e.g. at the mobile device **12_1, 12_2, ..., 12_n**.

A handoff means or computer routine or algorithm **48** executes an access point assignment and subsequent handoff to the closest access points for determined locations and identifies a channel with the strongest signal, e.g. the best signal to noise ratio, of the mobile devices **12_1, 12_2, ..., 12_n** within the defined space **16**. More specifically, when one of the mobile units **12_1, 12_2, ..., 12_n**, such as the mobile unit **12_1**, is powered up, a position determining means or computer routine or algorithm **50** determines the location of the mobile device **12_1** within the defined space **16**. A scanning means or computer routine or algorithm **52** scans operational frequencies of the channels of all the access points within the defined space **16** to determine gradients of actual signal strengths between the mobile device **12_1** and each of the scanned frequencies. The scanned frequencies are presented in an order of the gradients, e.g. from the highest gradient to lowest, and are stored in a scanned frequencies memory **54**. A position calculating means or computer routine or algorithm **56** calculates a position of the mobile device **12_1**, e.g. the initial position **P1**, by comparing the actual signal strengths against the mapped signal strengths. Preferably, the position is determined from the relative signal strengths of the three strongest frequencies, normally the three closest stations. However, other numbers of frequencies/stations for determining the position of the mobile units can be used. A larger number gives greater positional accuracy. In some instances, less than three may identify the location of the mobile unit uniquely, particularly when walls and other physical obstructions are considered.

The determined position **P1** is stored in a position memory **58**. An access point assigning means or computer routine or algorithm **60** identifies a location of an access point with the strongest signal and assigns it to the mobile device **12_1**. A scanning frequencies identifying means or computer routine or algorithm **62** identifies frequencies of, preferably three adjacent channels, e.g. three access points **14_1, 14_3, 14_4** which are closest to the position **P1** which typically have the strongest signals. The three adjacent access points and corresponding frequencies of each associated channel are stored in a scanning frequencies memory **64**.

As the mobile device **12$_1$** moves from the position **P1** towards position **P2**, the signal strength between the mobile device **12$_1$** and the access point **14$_1$** is declining and signal strength between the mobile device **12$_1$** and the access points **14$_3$** and **14$_4$** is increasing. With the defined space **16** being mapped, the scanning means **52** periodically scans the three stored adjacent frequencies to collect the signal strength values between the mobile device **12$_1$** and the frequencies of the three closest access points as the mobile device **12$_1$** moves from the position **P1** toward the position **P2**. The position calculating means **56** calculates a new position of the mobile device **12$_1$**. Preferably, the exact position of the mobile device **12$_1$** is triangulated by comparing the actual signal strengths at the three measured frequencies. A velocity determining means or computer routine or algorithm **66** compares location results of the periodic scanning and determines speed and direction of movement of the mobile device **12$_1$** or any other mobile device within the defined space **16**. Based on the speed and direction of the mobile device, a future position predicting means or computer routine or algorithm **68** predicts future positions of the mobile device as well as projected future signal strengths between the mobile device and access points of the cell in which the mobile device is located and adjacent cells.

If it is determined that the mobile device **12$_1$** is approaching a new position, e.g. the position **P2**, at which the map **42** shows a different access point will have stronger signal, the access point assigning means **60** assigns the mobile device **12$_1$** a new primary communication access point which, preferably, has the strongest signal. By consulting the map **42**, the scanning frequencies identifying means **62** identifies the frequencies of the, preferably, three access points **14$_1$**, **14$_4$**, **14$_6$** that provide the strongest signals with the new position **P2**. In this example, the three access points which measure location stay the same, but the access point through which communication occurs shifts from **14$_1$** to **14$_3$**.

As the mobile device moves toward location **P3**, one of the three location measurement access points changes, i.e., the three closest change from **14$_1$**, **14$_3$**, and **14$_4$** to **14$_3$**, **14$_4$**, and **14$_6$**. The change over from access point **14$_1$** to **14$_6$** is preferably done at the time which the position predicting means predicts the mobile device will become closer to access point **14$_6$** than to access point **14$_1$**. In this manner, if the mobile device is moving so fast compared to the location sampling interval that it will be out of range of access point **14$_1$**, it will still seamlessly triangulate its position off of access points **14$_3$**, **14$_4$**, and **14$_6$**. The three new adjacent access points and corresponding frequencies of each associated

channel are stored in the scanning frequencies memory **64** to be periodically analyzed by the position determining means **50** to monitor the position of the mobile device **12_1**. The AP assigning means **60** accesses the map **42** and the scanning frequencies memory **64** to retrieve the frequencies of the new access point **14_6** and the discontinued access point **14_1**. This frequency change is communicated to the mobile device to cause a seamless change in the scanning frequencies without searching all frequencies looking for the new closest access points.

With continued movement to **P3**, the communication frequency is changed from the frequency of access point **14_3** to the frequency of access point **14_6**.

In some circumstances, the access point assigning means **62** may not assign a mobile unit to the access point with the strongest signal. The access point assigning means **60** confers with an arbitration means or computer algorithm **70** to determine the best overall distribution of the assignment of the mobile devices to the access point. In one example, the arbitration means **70** looks to see if any access point is over-crowded or approaching capacity. If a mobile unit is approaching a near capacity access point, the handoff is deferred until the map **42** shows it is moving beyond a signal strength of its current access point or another mobile device moves out of the over-crowded access point's region. As a second example, the arbitration means **70** projects how long the mobile unit will be in the new access point region from the trajectory of its projected velocity and the map. If the projected trajectory will only pass briefly through the new zone without loosing satisfactory signal strength from its current access point or the next yet projected access point, the handoff from the current access point to the next access point and from the next access point to the next yet access point can be skipped in favor of a handoff directly from the current access point to the third next yet access point.

With continuing reference to FIGURE 2 and further reference to FIGURE 3, to improve the accuracy and reliability of position tracking, more than three scanning frequencies of the neighboring access points are selected for scanning to track the position of the mobile device **12_1, 12_2, ..., 12_n**. The number of the adjacent access points (scanned frequencies) varies as a function of the certainty of the position accuracy to minimize the number of channels to be scanned to determine the accurate position of the mobile unit **12_1** as it moves within the defined area **16**. As position becomes less certain, more nearby

access points are scanned; as the position becomes more certain, fewer access points are scanned.

More specifically, as the position calculating means **56** determines the position of the mobile device **12**$_1$, a certainty determining means **72** determines a certainty of accuracy of the determined location based on prespecified factors such as longer intervals between samplings, motion at high rate of speed, motion along an erratic trajectory, or the like. The determined certainty is compared with a threshold which is preferably predetermined in advance based on certain criteria. Of course, it is also contemplated that the threshold can be varied to restrict or increase the number of scanned frequencies based on the system requirements. If the determined certainty is below the threshold, the scanning frequencies identifying means **62** accesses the area map database **42** and selects all operational frequencies existing within the area **16** for scanning. The scanned frequencies are presented in an order of the gradients, e.g. from the highest gradient to the lowest, and are stored in the scanned frequencies memory **54**. The position calculating means **56** recalculates the position of the mobile device **12**$_1$, and the certainty determining means **72** determines the certainty of the recalculated position. The redetermined certainty is compared with the threshold. If the determined certainty is still below the threshold, the position calculating means **56** requests more frequencies from the scanned frequencies memory **54**. The certainty determining means **72** recalculates the certainty each time an additional frequency is added to the position calculation and compares the determined certainty with the threshold until the threshold is reached and/or exceeded. The identified optimal adjacent access points and corresponding frequencies are stored in the scanning frequencies memory **64** to be scanned by the scanning means **52** to determine the speed and position of the mobile device **12**$_1$ with more accuracy.

The invention has been described with reference to the preferred embodiments. Modifications and alterations will occur to others upon reading and understanding of the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.